DOCUMENT RESUME

ED 233 896 SE 042 805

TITLE	Physics: A Career for You?
INSTITUTION	American Inst. of Physics, New York, N.Y.
PUB DATE	77
NOTE	16p.
AVAILABLE FROM	American Institute of Physics, 335 East 45th Street, New York, NY 10017 (single copies free; multiple copies $0.75 each, prepaid).
PUB TYPE	Reference Materials - General (130) -- Guides - General (050)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Career Awareness; College Programs; *Employment Opportunities; Graduate Study; *Physics; Resource Materials; *Science Careers; Science Education; Secondary Education; *Secondary School Science

ABSTRACT

Information is provided for students who may be interested in pursuing a career in physics. This information includes the type of work done and areas studied by physicists in the following areas: nuclear physics, solid-state physics, elementary-particle physics, atomic/molecular/electron physics, fluid/plasma physics, space/planetary physics, acoustical physics, biophysics, astrophysics, and "other" physics areas (such as physics education, physics history/philosophy, or statistical physics). Other information focuses on types of positions available with master's/doctoral degrees, and graduate programs. Additional information is also provided in the form of answers to questions commonly asked by students. These include: (1) Why would I want to study physics? (2) Can I help society by being a physicist? (3) Can women be physicists? (4) Can I study physics and then decide to go into another field? (6) What are the employment prospects in physics? (7) What would I earn as a physicist? and (8) How can I get together with a physicist to find out more about physics as a career? A list of books about physics/physicists and the source for a list of schools offering physics/astronomy programs are provided as answers to two additional questions. (JM)

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PHYSICS

PHYSICS

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The American Institute of Physics was founded in 1931. It is chartered as a membership corporation with leading societies in the fields of physics and astronomy as members. The Institute combines into one operating agency those functions which can best be done by the societies jointly. Its purpose is the advancement and diffusion of the knowledge of physics and its applications to human welfare.

To this end the Institute publishes scientific journals; provides abstracting and indexing services; serves the public by making available to the press and other channels of public information reliable communications on physics and astronomy and their progress; carries on extensive manpower activities; encourages and assists in the documentation and study of the history and philosophy of recent physics; cooperates with local, national, and international organizations devoted to physics and related sciences; and fosters the relations of the science of physics to other sciences and to the arts and industries.

The physicists represented by the Institute number more than 60,000 members of its Member Societies. In addition, approximately 6500 students in over 500 colleges and universities are members of the Institute's Society of Physics Students, which includes the honor society component Sigma Pi Sigma. Industry is represented through some 120 Corporate Associate members.

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The ring-shaped chamber seen in this overhead view is the main part of an experiment called "Scyllac." The aim of the experiment is to set up and control a nuclear-fusion reaction in deuterium gas inside the chamber, as a possible new source of energy. The ring measures 4.8 meters (about 15½ feet) across.

Los Alamos Scientific Laboratory

PHYSICS:
A Career
for You?

Physics is the most boring, tiresome and dull career you could possibly have.

Physics is the most challenging, innovative, exciting and productive career you could possibly have.

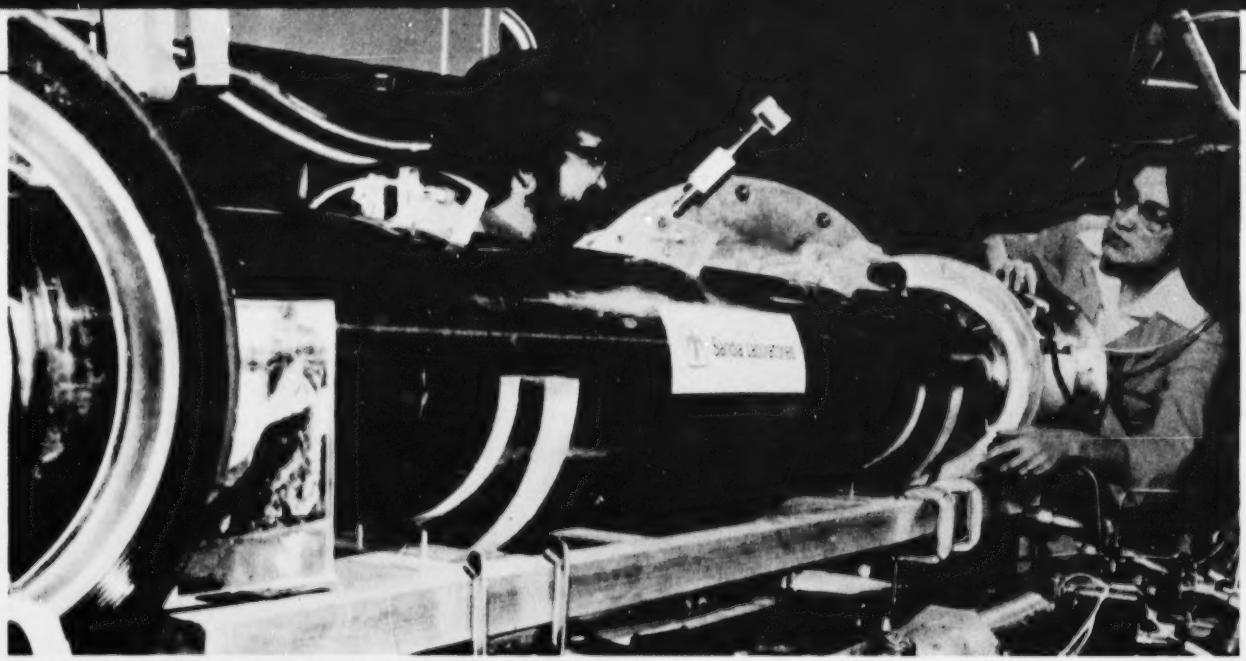
Which of these two statements is true? Either of them could be. It all depends on you. It depends on whether or not you have the necessary aptitude, interest, and skills. You will have to examine both yourself and the field of physics before you decide which statement applies to you.

Because physicists are highly individualistic and do a wide variety of different things, there is no list of characteristics and interests you need to have if you are to enjoy physics and to contribute to physics. A sense of dedication is a basic requirement. An interest in mathematics and science is another obvious requirement. But all of these are just as necessary for success and achievement in many other professions. You will have to look further.

You might ask yourself these questions:

- **Am I interested in discovering how things work?**
- **Am I more interested in discovering how the same idea can explain a variety of different devices or problems rather than just a single one?**
- **Am I more interested in finding exact, quantitative explanations rather than being satisfied with generalities?**

Most physicists would answer "yes" to these three questions. If you too have answered "yes" to these questions, you may well enjoy being a physicist. Let's look more deeply into what a physicist does and find out what preparations he or she needs.



Sandia Laboratories

Physicists design their experimental equipment to do the job rather than to look fancy. The tube here is the high-energy, gas-filled, electron-beam laser, which first achieved lasing of argon fluoride.

What does physics cover? We almost wish *that* question had not come up! Physics has such a broad scope and plays such a basic role in all science and engineering disciplines that it is hard to define.

We could define physics as "the study of nature." This indicates its breadth, but does not show how it differs from the other sciences.

We could define physics as "the study of the structure of matter, the nature of radiation, and the interaction of radiation and matter." This is a bit better, but still does not show clearly and simply how it differs from some of the other sciences.

We could define physics as...but wait! This process of definition could go on indefinitely. Let us look instead at the major branches of physics—and some closely related disciplines—as they exist today. Perhaps you will then be able to work out your own definition.

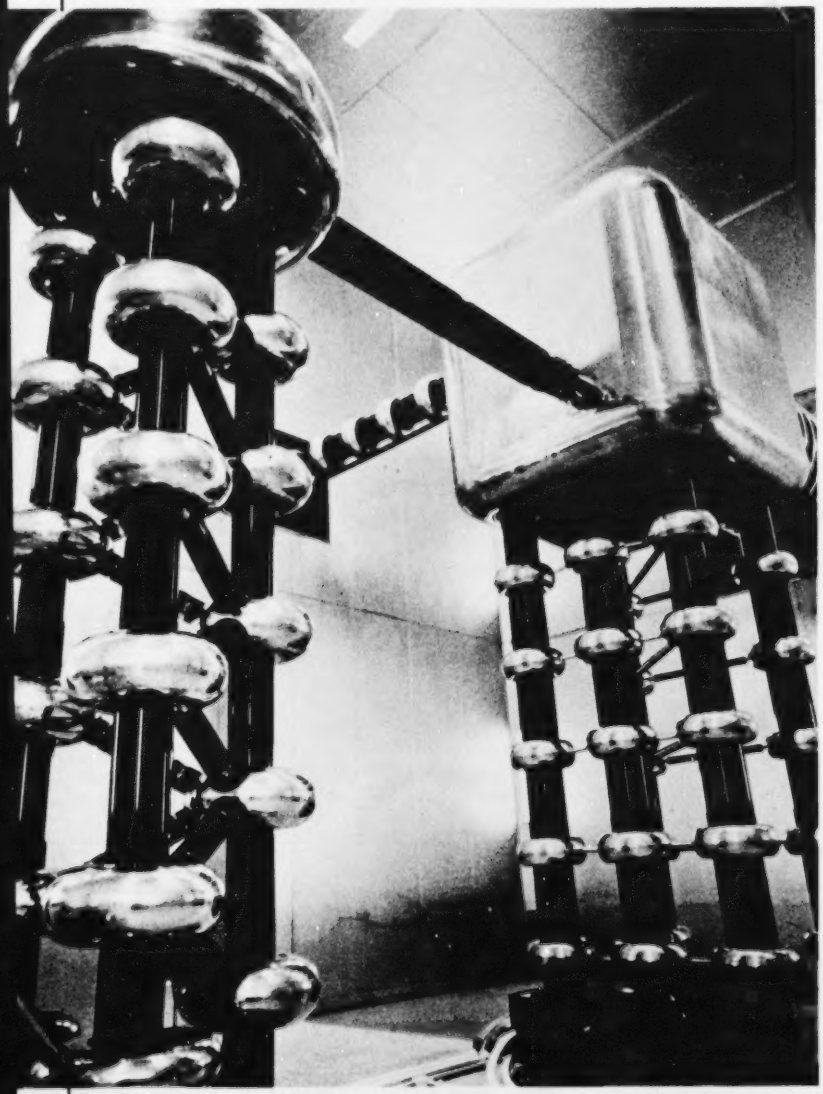
Solid-state physicists investigate the properties of materials such as metals, alloys, semiconductors and insulators. The transistor, the best known result of their research, is so widely used that every home has scores of them in television sets, stereos, radios, pocket calculators and electronic ignition on cars. Research now going on may show how to grow useful-sized single crystals of metals, which would be thousands of times stronger than the best steel available today.

Nuclear physicists are interested in what happens inside the atomic nucleus. They use large accelerators to smash nuclear particles together to find out what they are made of and how they interact. Nuclei may seem too small to have much effect on our lives, but many homes now get their electricity from nuclear power plants, and many lives have been saved by the radioactive tracer elements used by doctors to diagnose medical problems.

Optical physicists are interested in light—how to generate it, how to control it, how to describe it. We are all familiar with eyeglasses, binoculars, and microscopes. But research into lasers has already been applied to everything from eye surgery to cutting tools for metal plates and may in the future lead to the development of triggers for fusion power plants. Much of the research now going on to find efficient ways of turning sunlight into electricity is done by optical physicists.

Elementary-particle physicists take up where nuclear physicists leave off; they want to learn about Nature's most fundamental building blocks, which

Where the Fermilab protons originate. The Cockcroft-Walton accelerator (named for its two physicist inventors) provides protons to be injected into the "big machine" at Fermilab.



Fermi National Accelerator Laboratory

combine to form the particles inside a nucleus. This research is so basic that applications to our everyday lives are many years in the future, but the same was true of nuclear physics forty or fifty years ago.

Atomic, molecular and electron physicists study how the electrons and the nucleus inside an atom interact, and how atoms combine to form molecules. Their work is providing the basis for understanding chemical reactions. They can identify the composition of an unknown material by examining the light given off when a very small sample is heated—this technique (called spectroscopy) has been applied to everything from medical tests in the hospital to learning how Renaissance artists mixed their paints.

Fluid and plasma physicists both investigate the flow of fluids—liquids and gases—but plasma physicists are interested in electrically charged fluids while fluid physicists are interested in uncharged fluids. Applications of the work of fluid physicists can be seen all around us, from the streamlining of your car to the design of the jet engine in a plane. The plasmas studied by plasma physicists are generated at high temperatures and are important in such varied areas as the re-entry of space vehicles into the atmosphere and the attempt to develop large controlled-fusion devices to generate electrical power.

Space and planetary physicists have become more numerous with the coming of the Space Age. Space physicists study the region between the planets; this may be a vacuum as compared with conditions on Earth's surface; but it still contains many nuclear particles, atoms, molecules and meteorites, and is traversed by various kinds of radiation. All these things have to be considered when we design protection systems for astronauts and satellites for weather forecasting and for long-range relay of television programs and telephone calls. Planetary physicists, on the other hand, are more interested in conditions closer to home, rang-

General Motors Research Laboratory

Many physicists today work with lasers. The light from lasers (bright red in the example shown here) is unusually pure and well-focussed and often very powerful. Note that the experimenters in the photograph wear safety goggles to protect their eyes.

ing from the upper atmosphere to the depths of the oceans and the Earth itself. Long-range weather prediction, studies of the migration of fish along ocean currents and exploring for new oil fields are all applications of the work of planetary physicists.

Acoustical physicists study sound and its transmission. Although theirs is one of the oldest branches of physics, much of their work is basic research, and most of it has definite applications in our daily lives. Your stereo tape deck, the concert hall where you heard a rock concert or a symphony orchestra, the hearing aid you might have to use in the future and the ultrasonic scanner used by doctors—these are just a few of the everyday applications. Many acoustical physicists work in other areas, including studies of shock and vibration, noise and of underwater sound. Acoustical physics overlaps with the life sciences, too, in the study of the psychology and physiology of sound and of speech communication.

Biophysicists are growing in number as increasing attention is being given to developing a basic, quantitative understanding of living things and how they operate. Techniques developed in other branches of physics are now being applied to biological problems. The physical mechanisms of seeing, hearing, neural-electrical pulses, and the effects of x rays and nuclear particles on cells and tissues have been studied for a number of years. More recently, efforts to understand the composition of complex biological molecules such as proteins and DNA, which carries genetic information for the body, show promise of fantastic advances in medicine.

Astrophysicists have the largest possible laboratory—the universe. How old is the universe, and how did it start? How long will the universe last, and how will it end? Or is there a beginning and end of the universe? How do stars, including our Sun, form, mature and die? Should we try to "listen" for radio messages from extraterrestrial life? These are only a few of the exciting questions of interest to astrophysicists.

"Other" physicists include over one-third of the total number of physicists. Because of their broad interests, physicists become involved in such a wide variety of research areas that we can't enumerate them all. Some of the research areas in this broad category are physics education, history and philosophy of physics, statistical and thermal physics, electromagnetism and mechanics. A relatively high percentage of physicists of all backgrounds go into various types of administration.

Before deciding on physics as a career, you need to consider more than just which research areas interest you. You need to think ahead to the type of job you want once you have obtained your degree and have become a physicist. Your academic work is not an end in itself but only a means by which you prepare for your career. What you want to do should affect how you plan your academic work.

Because physics is used in so many different ways, it is impossible to describe "the" physics career. As a physicist, it is unlikely you would be an isolated individual working alone in a laboratory. You might be part of a research team. You might work with scientists from other disciplines. You might work with students as a teacher. In any of these roles you would interact with others.

Although we cannot describe "the" physics career, we can talk about some of the broad categories in which physics careers fall.

Your career as a physicist will depend on your:

- **type of work**
- **degree level**
- **field**
- **type of employer**

The type of work you choose can be research, development and design, teaching or administration.

Your degree level can be bachelor's, master's, or doctorate.

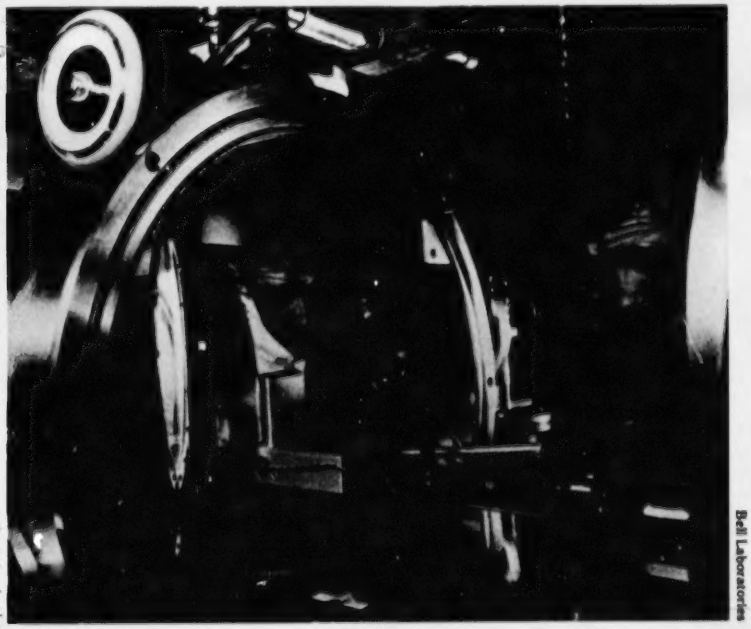
Your field can be any of those mentioned above, or some other field related to them.

Your employer can be an educational institution, an industrial firm, a government laboratory, or a non-profit research center.

Of course, your choices are not independent. Some combinations of options don't exist—for example, you cannot do development and design work with just a bachelor's degree in relativistic

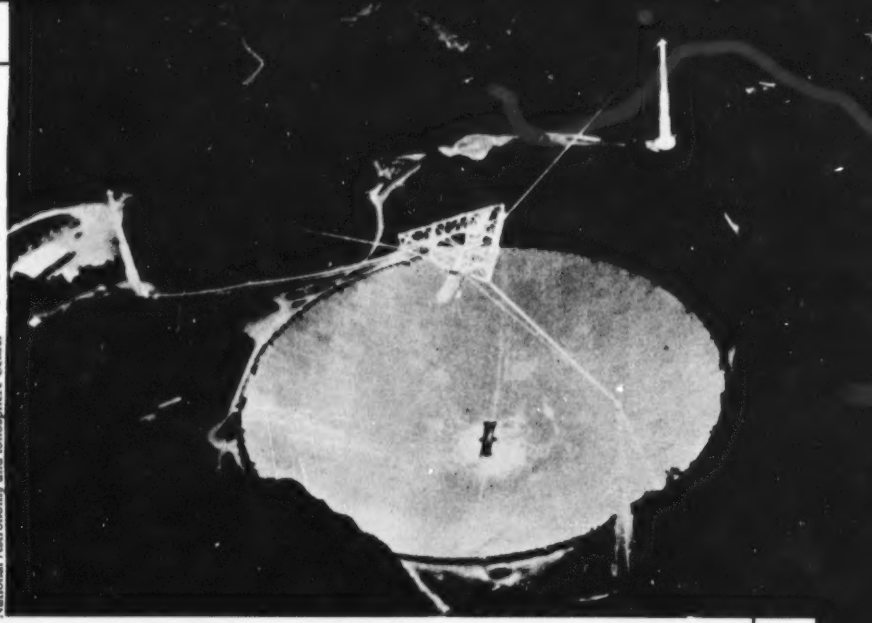
General Motors Research Laboratories

Studying the properties of materials is nowadays an important part of physics. The material in our photograph is polyethylene, with a pattern of stresses made visible by polarized light. (Enlarged about 1000 times.)



Bell Laboratories

Physicists study the nature of solids with this apparatus (an "interferometer") at Bell Laboratories. The experimenter in the photograph uses a large mirror to help him check alignment in the optical components—lenses, small mirrors, prisms, etc.—of the equipment.



National Astronomy and Ionosphere Center

Astrophysicists have the whole universe for a laboratory. With instruments such as this radio telescope at the NSF-supported Arecibo Observatory in Puerto Rico they can receive radio waves from distant stars and galaxies. Its diameter of 330 meters (about 360 yards) makes the Arecibo telescope the largest single-dish radio telescope in the world.

astrophysics for an industrial firm. However, the possible options do offer an exciting variety of career choices.

Different types of jobs are open to you depending on the degree you hold. Your job will be different if you have a doctorate degree than it would be if you have only a bachelor's or a master's degree.

With a bachelor's or master's degree, you are more likely to engage in design and development work, teaching, or administration than in research. In design and development work, you would probably be employed by an industrial firm, a government laboratory or a non-profit research center to apply already developed theory to specific problems. You would, most likely, be working closely with people who have engineering backgrounds, complementing their more specific training with your broader training in physical concepts. In teaching, you would probably teach at a high school or two-year college. Administrative positions are available with all types of work and employers, but for these jobs you usually need to have experience in the field first.

With a doctorate, you are prepared for a research career and are expected to have a high degree of initiative and responsibility for your research program. Your research program can fall anywhere in the range from "basic" through "applied," depending upon your interests and those of your employer. Because today's basic research leads to tomorrow's applied research, a division into basic and applied research is somewhat artificial and may reflect more your own orientation than the content of your research program. However, research at a college or university is more likely to tend towards the basic end of the spectrum with less concern for possible applications.

At an industrial laboratory, your research is more likely to tend towards the applied end of the spectrum, being somewhat directed by the interests of the company for which you work. In practice, your flexibility in choosing research problems can be nearly as great at an industrial laboratory as at a college or university.

Research at a government laboratory or a non-profit research center lies in the middle ground between an industrial laboratory and a college or university. Some operate in much the same manner as industrial laboratories, while others operate essentially as universities without students. All of these offer the opportunity for a challenging, productive research career.

At a college or university, the balance between research and teaching depends upon your interests and those of the college or university, with colleges tending to place greater emphasis on teaching and universities tending to place greater emphasis on research.

Regardless of employer, a surprisingly large number of physicists become involved in administration, particularly later in their careers.

In addition to those who remain in physics as a career, a substantial portion of those receiving bachelor's degrees in physics use their physics training as the basis for a career in another field. Some accept employment in a physics-related field immediately following graduation, while others go on to graduate work in another field. In any event, your training as a physicist provides an extremely flexible background for a variety of careers.

General Motors Research Laboratories

More than 900 institutions in the United States offer a bachelor's degree in physics. A listing of these institutions is available from the American Institute of Physics. You would enter these institutions as a freshman after completing your high-school studies or as a junior after completing an approved program at a two-year college.

The programs offered by these institutions have much in common, but they do vary in emphasis and detail. Generally the programs are flexible enough for you to tailor them to your particular career interests. Full information on the programs offered by an institution is available from its catalog. You should request catalogs from several institutions before deciding on which of them to apply to for admission. You should plan to visit the campuses, if possible, before deciding which institution is best for you.

The bachelor's degree in physics normally requires four years of study. Many institutions offer a choice of two physics programs, with different orientations. They are often designated "research" and "general" programs.

The research program is designed to serve either as preparation for graduate study in physics or related sciences, or as preparation for employment in industry and research after receipt of the bachelor's degree. The research-program curriculum consists of approximately:

- one-fourth mathematics beyond algebra and trigonometry, chemistry, and other sciences;
- one-fourth social and behavioral sciences and humanities such as history, economics, sociology, languages, literature, philosophy, art and music, and
- one-half physics from the introductory level through specialized courses in particular fields. Many of these physics courses include laboratory work.

The general program is designed for students who want a considerable knowledge of physics but who do not plan a research-oriented career in physics. It can be useful to those planning careers in secondary-school science teaching, technical writing, medicine, law, science or technology-related administration, or business. A general program requires fewer courses in physics and mathematics, and provides time for more courses in other areas of interest.

Your preparation for a bachelor's degree in physics should start while you are still in high school. You should take as much mathematics and science as possible. If "enriched" or "advanced-credit" courses in physics or mathematics are offered in your high school, you should take them. You can obtain a bachelor's degree in physics without taking physics in high school, but the better your high-school preparation is, the more you will get from your college studies.

After completing your bachelor's degree in physics, you will probably continue your studies on the graduate level either immediately following graduation or while you are employed. About 350 institutions offer a master's degree in physics, and more than 200 offer a doctorate in physics. A listing of these institutions is available from the American Institute of Physics. Information concerning many of these graduate departments is presented in the annual book, **Graduate Programs in Physics, Astronomy and Related Fields,** which can be purchased from the American Institute of Physics.

In physics, as in any other profession, your education never ends. Once you have completed your formal education on campus, you will continue to keep abreast of developments in your field and to make your own contribution to these developments. As a member of the physics community, you want to become a member of one or more of the professional societies in physics that are listed on the inside back cover.

Physicists study the environment. "Smog" in the atmosphere is the result of reactions between sunlight and chemicals polluting the air; With the apparatus in this photograph physicists can reproduce and investigate the same reactions in the laboratory. By using mirrors to reflect infrared radiation back and forth in this 4-meter long chamber until the radiation has traveled 120-meters, "smog" constituents can be measured at concentrations as low as a few parts per 100 million.

M. D. Anderson Hospital and Tumor Institute

Physics in the hospital. Medical physicists use devices such as the betatron (visible here on the TV monitor screen) to help diagnose and treat illness. This betatron, at M.D. Anderson Memorial Hospital in Houston, Texas, generates electrons with 18.5 million electron volts energy for radiation therapy. Doctors view it in action by closed-circuit TV to avoid receiving repeated radiation doses themselves.

Why would I want to study physics?

Most importantly because it's fun. You enjoy the challenge of discovering new understanding of the physical world about you, gaining insight into its most fundamental description, and communicating your understanding and insight to others. You enjoy the precision of a mathematical description of the universe coupled with the chance to devise and build experiments to test your ideas. But most importantly because you enjoy it.

Can I help society by being a physicist?

Yes, but the benefits to society are likely to be long-term benefits rather than short-term ones. Physics is the most basic of all the sciences and as such is the wellspring for understanding other sciences—such as chemistry and biology—and for the applications developed in the engineering fields.

Can women be physicists?

Yes. Although only about 3% of the present physicists are women, the percentage is growing. The booklet, **Women in Physics,** available from the American Physical Society, provides a frank discussion of careers in physics for women.

Bell Laboratories

Physics helps the phone company. Here we see a switching system that uses the latest in solid-state electronics to complete up to 550,000 long-distance connections per hour. Ever since the invention of the transistor, solid-state physicists have played an important role in the development of electronic devices—particularly for the communications industry.

Los Alamos Scientific Laboratory

Physicists work outdoors, too. In New Mexico this drill rig is part of a geothermal energy project. The aim is to drill down through the rock to natural underground reservoirs of hot water that could be pumped out and used as an additional source of energy.

Can I study physics and then decide to go into another field?

Sure, many do. Almost one-third of physics bachelor-degree recipients go on to graduate work in another field. About one-half of those becoming employed immediately following graduation do not make extensive, direct use of their physics training. Since physics training provides a broad scientific background and the development of an analytic approach to problems, it is good preparation for a variety of fields. Your physics training is directly applicable in computer science and engineering disciplines; it is also useful background in medicine, law and business.

Xerox Corporation

All experiments require careful preparation of samples.

What are the employment prospects in physics?

At the bachelor's and master's levels, the employment prospects in physics are at least as good as those in other sciences and in most engineering disciplines. The prospects are dependent upon the economic conditions at the time you graduate. At the doctoral level, the employment prospects are less encouraging as a result of the employment decline in the academic area, which traditionally has employed a majority of doctoral-level physicists. While there is a continuing need for the most promising young physicists, there is likely to be strong competition for doctoral-level positions through the middle 1980's.

What would I earn as a physicist?

Your starting salary would depend upon the degree you hold and the economic conditions at the time you graduate. Starting salaries for physicists are generally higher than those in other sciences or in most engineering disciplines. The American Institute of Physics conducts annual surveys of physics graduates. You can obtain the most recent salary information by requesting free copies of the reports, "Survey of Physics Bachelor's Degree Recipients" and "Graduate Student Survey."

Could you suggest some books about physics and physicists?

To find out more about physics and physicists you may want to read the following:

- **Passion to Know: The World's Scientists,** by Mitchell Wilson, Doubleday, 1972. Mr. Wilson's book is based upon interviews with scientists at a number of research laboratories.
- **Biography of Physics** by George Gamow, Harper & Row, 1964. Dr. Gamow based the book on his experiences as a physicist starting in the 1930's. Also of interest are his books, **One, Two, Three...Infinity** and **Mr. Tompkins in Paperback.** The first is a very readable description of physical phenomena, while the second is a whimsical account of life in a two-dimensional world.
- **Einstein: The Life and Times** by Ronald W. Clark, World, 1971. This is a good biography of this most famous physicist.
- **Brighter Than a Thousand Suns: A Personal History of the Atomic Scientists** by Robert Jungk, Harcourt Brace, 1958. This is the story of the development of the atomic bomb during World War II; and the political ramifications which followed are still fascinting. Also look for his book, **The Big Machine,** about the internationally-run CERN accelerator located in Europe.

To keep up with current developments in physics, look for the following magazines which should be available in your local library:

- **Science News** is published weekly and has very readable accounts of current news in all sciences.
- **Bulletin of the Atomic Scientists** is published monthly and carries articles on social concerns arising from physics.
- **Physics Today** is published monthly and includes more detailed information about physics developments. Many of the articles assume a strong physics background.

Several of the AIP member societies have career booklets about their particular field which can be ordered directly from the Society (see inside back cover). The booklets available are **Acoustics and You** from the Acoustical Society of America, **A Career in Astronomy** from the American Astronomical Society, and **The Medical Physicist** from the American Association of Physicists in Medicine.

Brookhaven National Laboratory

Inside a particle accelerator. This is a proton's-eye-view of part of the linear accelerator that injects protons into the 30-billion-electron-volt accelerator at Brookhaven National Laboratory. The linear accelerator is 145 meters long (about 470 feet) and speeds protons up to an energy of 200 million electron volts before they enter the larger machine.

Where can I obtain a list of schools offering physics or astronomy programs?

Write to the American Institute of Physics for the free lists, "U.S. Institutions by Highest Degree Program" (physics) or "U.S. Institutions by Highest Astronomy Program".

How can I get together with a physicist to find out more about physics as a career?

Physics is a dedicated profession, and most physicists would be happy to discuss physics careers with you. The easiest way to arrange an appointment would be to contact the Physics Department Chairman at a four-year college or university in your area. Any of the larger four-year colleges or universities and most of the smaller ones have a Physics Department.

Member Societies of the American Institute of Physics

The American Physical Society has as its objective the advancement and diffusion of the knowledge of physics. All branches of fundamental and applied physics are generally included in its scope. Both experimental and theoretical researches are reported in its journals and meetings.

The Optical Society of America devotes itself to the advancement of optics, pure and applied, in all its branches. Its scope includes research in fundamental optics as well as problems concerned with design and production of optical instruments.

The Acoustical Society of America's purpose is to increase and diffuse the knowledge of acoustics and promote its practical applications. The scope includes architectural acoustics, engineering acoustics, noise, psychological and physiological acoustics, shock and vibration, speech communication, underwater acoustics, physical acoustics, and musical acoustics.

The Society of Rheology is composed of physicists, chemists, and engineers interested in "rheology," which is defined as the science of deformation and flow of matter. Rheology includes both phenomenological and molecular theories, instrumentation, and the study of materials such as plastics, metals, ceramics, rubbers, paint, glass, and foodstuffs.

The American Association of Physics Teachers provides a much needed forum for the discussion of the problems of teaching. In cooperation with other groups, it promotes the advancement of physics and emphasizes its place in the general culture.

The American Crystallographic Association has as its objective the promotion of the study of the arrangement of the atoms in matter, its causes, its nature and its consequences, and of the tools and methods used in such studies.

The American Astronomical Society has as its purpose the advancement of astronomy and closely related branches of science.

The American Association of Physicists in Medicine's purposes are to promote the application of physics to medicine and biology, to encourage interest and training in medical physics and related fields, and to disseminate technical information in medical physics.

The American Vacuum Society's purpose is the advancement and diffusion of the knowledge of vacuum science, both fundamental and applied. Its scope includes all areas of science and technology wherein pressures below atmospheric are essential.

Student Program of the American Institute of Physics

The Society of Physics Students is the physics society explicitly designed for students. SPS membership is open to anyone interested in physics. Sigma Pi Sigma, the nationally recognized honor society component of the SPS, elects members on the basis of outstanding academic achievement.

For information about specific fields write to the appropriate society, care of

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